Nonlinear Analysis and Computer Simulations
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Editorial

Nonlinear Analysis and Computer Simulations: New Horizons in Theory and Applications

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Received: 26 November 2025; Accepted: 5 December 2025; Published: 5 January 2026

How To Cite: Cattani, C. Nonlinear Analysis and Computer Simulations: New Horizons in Theory and Applications. *Nonlinear Analysis and Computer Simulations* **2026**, *1*(1), 1.

1. Introduction

Computer Science has been one of the major scientific revolution of the 20th century. Our societies and life have been deeply transformed into a unified model within a modern and fast connected world. We can't even imagine how could be our digital world without internet and computers. Computer simulations have revolutionized our understanding of life and strongly interacts with the world around us to largely extend the boundaries of our knowledge.

From the simulation of complex physical phenomena and intricate biological systems, at the macro and nano levels, from cosmology to nuclear particles interaction, the power of computational techniques has become an indispensable tool of investigation in all scientific disciplines. Across a wide range of problems arising in all scientific and engineering disciplines the computer simulation enables to handle massive amount of data and massive amount of numerical computations for complex investigations. The most impressive contribution was given by one of the fundamental mathematical field: nonlinear analysis.

Nonlinear analysis is a fundamental branch of pure mathematics, dealing with a wide range of problems, in particular investigating uniqueness theorems and existence of solutions of nonlinear analytical problems. The search of solutions has been significantly improved by the increasing use of computers both for obtaining analytical series and numerical approximations. Such a kind of investigations have gained successful results and has been extended to study nonlinear problems in almost all disciplines. So that nonlinear analysis is crossing a variety of applied sciences from engineering to physics, economics, biology, medicine and even social sciences. In fact, with the modern highly technological instruments and advanced theoretical model an increasing number of new nonlinear problems are discovered thus leading to a constant need for more performing computational models.

The complexity of our world and the constant technological challenges can be seen in the intricate interdisciplinary exchanges in the most advanced research fields, from nuclear physics to fluid dynamics from the uncertainty of quantum physics to the volatility of financial markets. Therefore, we become more and more aware of the complex patterns and evolution of systems like e.g., biological, astrophysical, nuclear, new materials, systems. So that the intriguing nonlinearities of the real world become an attracting field of research full of challenges and new insights. Nonlinear mathematical analysis is the fundamental mathematical tool for understanding these complex behaviors, and it is used for modeling, prediction, search of solutions, problem-solving across almost all disciplines.

2. Theoretical Foundations and New Frontiers

In recent years nonlinear analysis has been growing very fast and giving significant results on several topics such as operators, perturbation analysis, global existence, stability, functional analysis, convergence, regularity, optimal control, variational methods, topology, differential problems. The search of solution and the proof of convergence has lead to original numerical schemes and the development of new computational methods. So that the computer simulations has becoming a fundamental tool of investigation of nonlinear problems. The major scientific contribution of nonlinear analysis is not only from pure mathematics but also for the many applications in real world problems. When facing the complexity of linear problems the first approach is to linearize a problem thus reducing the complexity and the computations. However given the rapid growth of computers and computational methods the challenge for solving nonlinear problems has been one of the major task of modern scientific research. Classically, one of the most known nonlinear theory is fluid mechanics described by nonlinear partial differential equations. Some other nonlinear differential problems arise in relativity, biology, population dynamics, chaos and bifurcation, quantum physics, geophysics, image analysis and data analysis, graph theory and networks. So that far distance topics of research share the common property of being described by similar nonlinear differential equations problems. The dependence of climate prediction on a large amount of parameters is shorty summarized as a complex model, but the many attempts to forecast the climate evolution rely on the solution of nonlinear differential problems. Moreover, many new nonlinear computational algorithms have been used to study big data (like in climate modeling) to predict the evolution of climate and the fast growing of data analysis implied a more precise forecasting and these results were impossible to obtain with classical mathematical methods even in recent times.

The impact of computers and computer simulations is not limited to theory. In fact, the application to the analysis of real-world problems are transforming our society and pushing our world to unexpected global challenges like e.g., the world climate prediction, the mission to Mars, the genomic data bank and DNA decoding, the nuclear fusion, the large hadron collider for the analysis of elementary particles, autonomous and robotic systems, global connections and communication networks and so on. For instance, thanks to the modern analysis of DNA we can have personalized medicine for more effective treatments and extend our healthy life. Thanks to computer simulations we can have a better prediction of the climate on environment and the climate change even on long-term, thus pushing our societies toward a more sustainable life by reducing the impact of technologies on the environment. It is also thanks to the computer simulations and AI that we have improved the efficiency of autonomous systems (drones, cars, robots, …) that have enormously improved the quality of our life and healthcare.

3. Cross-Disciplinary Synergy in the Nonlinear Studies

One of the major feature of the nonlinear analysis is its interdisciplinary nature. Nonlinear analysis was originally born as one of the main research field in pure mathematics, but in the last Century given its cross-synergy with computer simulations was growing fast as an efficient tool of investigation in a variety of applied sciences—engineering, physics, economics, biology, and even social sciences. The thin border between theoretical mathematics and applied research became more and more invisible, leading to a strong and fruitful cooperation and intersection. In this field, we have not only papers dealing with abstract mathematical models of pure mathematics but also significant models that solve real-world problems. For instance, we have original studies in the theory of nonlinear partial differential equations from abstract point of view but also practical point of view in modelling dynamical systems, chaos, physical interactions, wave propagation, nonlinear materials (including biological tissues, optical materials, metamaterials) but also in signal and image analysis. There follows that these studies provide new perspectives not only in theory but especially in advanced extreme engineering applications. Computer simulations have helped to increase the cross disciplinary synergy among disciplines. They represent not only computational models and algorithms but also the most suitable tool to investigate the nonlinearities of hard complex problems from machine learning to artificial intelligence, from optimization to automatic design, from big data to image analysis. Thanks to this cross-fertilization and synergy that we an easily explore new research field and we can push forward the boundaries of our knowledge.

4. Journal Mission

This journal focuses on original papers for modeling nonlinear problems by using suitable computer simulations. In particular, this journal is dealing with convergence, existence, stability, optimization, functional spaces, operators, differential, integral problems. The analysis of differential problems with ordinary, partial, differential or integral equations also in presence of a stochastic term, modelling mathematical, physical, biological, financial, engineering models is an important topic of nonlinear analysis. The simulations of fluid dynamics problems or complex large scale systems (depending on a large number of parameters) together with the analysis of uncertainty that require a suitable smart computational tools to handle a large amount of computations are also fitting with the scope of this journal.

Nonlinear Analysis and Computer Simulations journal is providing a platform for sharing original works both in theory and applications that are modeling nonlinear problems by using suitable computational tools. The main aim of the journal is to play a role both in the theory and applications of nonlinear models. We call for papers where new original techniques, models, methods, algorithms and computer simulations might open new perspectives in research.

The Journal of *Nonlinear Analysis and Computer Simulations* is collecting original researches in the field of nonlinearity bringing together significant computational tools. Contrary to the linear approximation, nonlinear models propose original methods to study theoretical pure problems and practical applications. The outstanding power of computer simulations greatly enhances the solution of complex problems thus improving also predictive modeling, problem solving in almost all research fields from pure mathematics to any engineering applications and physical theories. Thus being open to any progress in simulation methods, computational tools, and their real-world applications.

5. Significant Milestones and Trends in the Solution of Nonlinear Differential Equations

Nonlinear differential equations are one of the fundamental topics of nonlinear analysis. However, it is only a small fragment of the large realm of the nonlinearity world. In this section the major contributions to search of solutions for a such kind of equations is given as an example of the rich field of research. During the last Century and in particular during the last decades there has been an increasing challenge to study nonlinear problems. Given the fast exponential growth of computers the analysis of complex problems became one of the major field of research and interest. In particular the main attention was paid to the solution of nonlinear differential problems by discovering a variety of methods for solving such kind of problems. Any of these methods has been used and improved to solve more complex problems so that the majority of papers dealing with nonlinear differential problems were achieving their tasks only by means of suitable computer simulations based on a such methods for solving nonlinear differential equations. There follows that each computational method gave rise to a large amount of papers accompanying an exponential growth in the number of nonlinear studies. By limiting ourselves only to the most popular and smart methods used to solve (linear) nonlinear (ordinary or partial) differential problems we have the Adomian decomposition method (ADM) [1,2], the auxiliary equation method [3–6], Picard's or terative methods that use an initial approximation to generate a sequence of approximations that might converge to the solution [7]. Similar to this there are the so-called perturbation methods where the solution is expressed in term of a power series in a small parameter. The homotopy perturbation method [8,9] and the homotopy analysis method (HAM) are based on the definition of a suitable series depending on a convergence-control parameter [10–12]. The analytical approximation is defined in a such a way to be specifically obtained by a computer algebra simulation. Variational methods and variation iteration methods are based on suitable sequence of functions that converge to the exact solution under an optimal condition [13–15].

Among the most smart methods to solve nonlinear partial differential equations there is the search for a class of exact solutions in the soliton's (travelling wave) theory [16–21] obtained with classical methods: inverse scattering [21], Backlund transformation [22–24], direct (Hirota) method [25,26] Painlevé expansion [27]. Semi-analytical methods enables to convert the search of solution of PDE into the search of solutions for nonlinear ordinary differential equations. The corresponding solutions are generated by the balance between nonlinearity and linear dispersion. With respect the balancing method we have to mention the (G'/G)-expansion method [28–32], the Kudryashov method [33], the exp-expansion method [34,35] based on a series of exponentials. The F-expansion method is using polynomials of a given function [36,37], ratio of polynomials sums [38] and exponential sums [39–41].

By a particular choice of the function we have the tanh method [42] which is based on a tanh polynomial and the Riccati equation and the Jacobi elliptic functions [43–46]. The sine–cosine method [47,48] is using power of spheric functions. Several more methods are used often are generalizations or can be used only for some special PDE's like e.g., the sine-Gordon expansion method [49].

Given the rapid growing of computer simulations and computer's power the above methods, although significant, represent only a nonexausthive list of papers and methods dealing with the numerical solution of nonlinear differential equations and this topics is only a small fragment of the large field of nonlinearity. Therefore the main scope described in the next section can only give a limited examples of the topics that fit with the mission of this journal.

6. Aims and Scope of the Journal

The journal *NACS* focuses on theoretical mathematical modeling where innovative computer algorithms and simulations play a fundamental role in elucidating, exploring, and visualizing complex solutions. Nonlinearity is inherent to modern complex systems, and computational methods are uniquely positioned to unravel and depict these intricate behaviors. *NACS* particularly welcomes contributions that successfully bridge mathematical theory with significant computational and graphical experimentation.

Recognizing the critical role of nonlinear modeling across disciplines, *NACS* also places special emphasis on mathematical computational models applied to practical fields such as Engineering, Physics, Computational Science, Biology, and any interdisciplinary domain grappling with complex nonlinear problems. The journal actively promotes the integration of theoretical insights with tangible applications. The main scope of the journal are summarized but not limited to the following:

Theoretical Mathematical Modeling & Analysis:

- Nonlinear Differential Equations
- Dynamical Systems
- Stability Analysis
- Optimization
- Convergence
- Control
- Operators
- Functional spaces
- Chaos and Bifurcations
- Nonlinear Wave Dynamics and Solitons
- Nonlinear Mathematical-Physics problems
- Nonlinear materials
- Multiscale and Stochastic Models
- Complex Networks and Graphs
- Number Theory (with relevance to nonlinear phenomena/computation)

Computational & Graphical Methods:

- Advanced Numerical Methods
- Machine Learning (applied to modeling/simulation/analysis)
- Signal and Data Analysis
- Image Analysis and Processing
- Scientific Software Development and Visualization

Original research and review papers dealing with problems somehow related to nonlinearity and computer simulations are also welcome.

7. Conclusions

Looking ahead to the future of the journal, envisioning what the journal will ultimately develop into, anticipating the transformative changes it will bring to the field. The interplay between *Nonlinear Analysis and Computer Simulations* and its influence on theory and applications is the steady ground for building any modern mathematical and engineering research field. Efficient computational tools and models enable to handle the many complexities and uncertainties of real-world problems. Computational limitations disappear with the fast growing of computers and AI thus enabling to solve more complex analytical problems continuously arising from the more accurate observations of the real-world. Therefore technology, mathematics and computer science merge into a unique model that bring us toward the future opening the frontiers of a new scientific era.

Conflicts of Interest

The author declares no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

References

1. Adomian, G. *Nonlinear Stochastic Operator Equations*; Kluwer Academic Publishers: Alphen aan den Rijn, The Netherlands, 1986.
2. Adomian, G. *Solving Frontier Problems of Physics: The Decomposition Method*; Kluwer Academic Publishers: Alphen aan den Rijn, The Netherlands, 1994.
3. Jiong, S. Auxiliary equation method for solving nonlinear partial differential equations. *Phys. Lett. A* **2003**, *309*, 387–396.
4. Fendzi-Donfack, E.; Temgoua, G.W.K.; Djoufack, Z.I.; et al. Exotical solitons for an intrinsic fractional circuit using the sine–cosine method. *Chaos Solitons Fractals* **2022**, *160*, 112253.
5. Zhu, D.S. Exact solutions for the high-order dispersive cubic-quintic nonlinear Schrödinger equation by the extended hyperbolic auxiliary equation method. *Chaos Solitons Fractals* **2007**, *34*, 1608–1612.
6. Zhang, S.; Xia, T.-C. A generalized auxiliary equation method and its application to (2+1)-dimensional asymmetric Nizhnik–Novikov–Vesselov equations. *J. Phys. A Math. Theor.* **2007**, *40*, 227–248.
7. Traub, J.F. *Iterative Methods for the Solution of Equations*; Chelsea Publishing Company: New York, NY, USA, 1982.
8. He, J.-H. Homotopy perturbation method for bifurcation of nonlinear problems. *Int. J. Nonlinear Sci. Numer. Simul.* **2005**, *6*, 207–208.
9. He, J.-H. Application of homotopy perturbation method to nonlinear wave equations. *Chaos Solitons Fractals* **2005**, *26*, 695–700.
10. Liao, S.J. The Proposed Homotopy Analysis Technique for the Solution of Nonlinear Problems. Ph.D. Thesis, Shanghai Jiao Tong University, Shanghai, China, 1992.
11. Liao, S. Notes on the homotopy analysis method: Some definitions and theorems. *Commun. Nonlinear Sci. Numer. Simulat.* **2009**, *14*, 983–997.
12. Liao, S. *Homotopy Analysis Method in Non-Linear Differential Equations*; Springer: Berlin, Germany, 2012.
13. He, J.-H. Variational principles for some nonlinear partial differential equations with variable coefficients. *Chaos Solitons Fractals* **2004**, *19*, 847–851.
14. He, J.-H. Variational approach to (2+1)-dimensional dispersive long water equations. *Phys. Lett. A* **2005**, *335*, 182–184.
15. Liu, H.-M. Variational approach to nonlinear electrochemical system. *Int. J. Nonlinear Sci. Numer. Simul.* **2004**, *5*, 95–96.
16. Russell, J.S. Report on Waves. In Proceedings of the 14th Meeting of the British Association for the Advancement of Science, New York, NY, USA, 23–28 September 1844; pp. 311–390.
17. Korteweg, G.; De Vries, D.J.. XLI. On the change of form of long waves advancing in a rectangular canal, and on a new type of long stationary waves. *Lond. Edinb. Dublin Philos. Mag. J. Sci.* **1895**, *39*, 422–443.
18. Adlam, J.H.; Allen, J.E. The structure of strong collision-free hydromagnetic waves. *Philos. Mag.* **1958**, *3*, 448–455.
19. Adlam, J.H.; Allen, J.E. Collision-free Hydromagnetic Disturbances of Large Amplitude in a Plasma. *Proc. Phys. Soc.* **1960**, *75*, 640–648.
20. Zabusky, N.J.; Kruskal, M.D. Interaction of 'Solutions' in a Collisionless Plasms and the Recurrence of Intial States. *Phys. Rev. Lett.* **1965**, *15*, 240–243.
21. Ablowitz, M.J.; Clarkson, P.A. *Solitons, Nonlinear Evolution Equations and Inverse Scattering*; Cambridge University Press: Cambridge, UK, 1991.
22. Wadati, M. Wave propagation in nonlinear lattice. *J. Phys. Soc. Jpn.* **1975**, *38*, 673–680.
23. Matveev, V.B.; Salle, M.A. Darboux *Transformation and Solitons*; Springer Series in Nonlinear Dynamics; Springer: Berlin, Germany, 1991.
24. Zait, R.A. Bäcklund transformations, cnoidal wave and travelling wave solutions of the SK and KK equations. *Chaos Solitons Fractals* **2003**, *15*, 673–678.
25. Hirota, R. Exact solution of the korteweg-de Vries equation for multiple collisions of solitons. *Phys. Rev. Lett.* **1971**, *27*, 1192–1194.
26. Hirota, R. *The Direct Method in Soliton Theory*; Cambridge University Press: Cambridge, UK, 2004.
27. Weiss, J.; Tabor, M.; Carnevale, G. The Painlevé property for partial differential equations. *J. Math. Phys.* **1982**, *24*, 522–526.
28. Wang, M.L.; Li, X.Z.; Zhang, J. The (G′G)-expansion method and travelling wave solutions of nonlinear evolution equations in mathematical physics. *Phys. Lett. A* **2008**, *372*, 417–423.
29. Zhang, H. New application of the (G′G)-expansion method. *Commun. Nonlinear Sci. Numer. Simul.* **2009**, *14*, 3220–3225.
30. Wen-An, L.; Hao, C.; Guo-Cai, Z. The (ω/g)-expansion method and its application to Vakhnenko equation. *Chin. Phys. B* **2009**, *18*, 400–404.

31. Zuo, J.-M.; Zhang, Y.-M. Application of the G′G-expansion method to solve coupled MKdV equations and coupled Hirota–Satsuma coupled KdV equations. *Appl. Math. Comput.* **2011**, *217*, 5936–5941.
32. Zhang, J.; Jiang, F.; Zhao, X. An improved (G'/G)-expansion method for solving nonlinear evolution equations. *Int. J. Comput. Math.* **2010**, *87*, 1716–1725.
33. Kudryashov, N.A. One method for finding exact solutions of nonlinear differential equations. *Commun. Nonlinear Sci. Numer. Simul.* **2012**, *17*, 2248–2253.
34. Roshid, H.O.; Azizur Rahman, M. The exp(-Φ(η))-expansion method with application in the (1+1)-dimensional classical Boussinesq equations. *Results Phys.* **2014**, *4*, 150–155.
35. Khan, K.; Akbar, M.A. The exp(−Φ(ξ))-expansion method for finding travelling wave solutions of Vakhnenko–Parkes equation. *Int. J. Dyn. Syst. Differ.* **2014**, *5*, 72–83.
36. Chen, H.-T.; Zhang, H.-Q. New double periodic and multiple soliton solutions of the generalized (2+1)-dimensional Boussinesq equation. *Chaos Solitons Fractals* **2004**, *20*, 765–769.
37. Zhang, D. Doubly periodic solutions of the modified Kawahara equation. *Chaos Solitons Fractals* **2005**, *25*, 1155–1160.
38. Li, W.-W.; Tian, Y.; Zhang, Z. F-expansion method and its application for finding new exact solutions to the sine–Gordon and sinh-Gordon equations. *Appl. Math. Comput.* **2012**, *219*, 1135–1143.
39. He, J.-H.; Wu, X.-H. Exp-function method for nonlinear wave equations. *Chaos Solitons Fractals,* **2006**, *30*, 700–708.
40. Xu, F. Application of Exp-function method to Symmetric Regularized Long Wave (SRLW) equation. *Phys. Lett. A* **2008**, *372*, 252–257.
41. Ma, W.; Huang, T.; Zhang, Y. A multiple exp-function method for nonlinear differential equations and its application. *Phys. Scr.* **2010**, *82*, 065003.
42. Fan, E.G. Extended tanh-function method and its application to nonlinear equations. *Phys. Lett. A* **2000**, *277*, 212–218.
43. Liu, S.; Fu, Z.; Liu, S.; et al. Jacobi elliptic function expansion method and periodic wave solutions of nonlinear wave equations. *Phys. Lett. A* **2001**, *289*, 69–74.
44. Fu, Z.; Liu, S.; Liu, S.; et al. New Jacobi elliptic function expansion and new periodic solutions of nonlinear wave equations. *Phys. Lett. A* **2001**, *290*, 72–76.
45. Liu, G.-T.; Fan, T.-Y. New applications of developed Jacobi elliptic function expansion methods. *Phys. Lett. A* **2005**, *345*, 161–166.
46. Zhang, H. Extended Jacobi elliptic function expansion method and its applications. *Commun. Nonlinear Sci. Numer. Simul.* **2007**, *12*, 627–635.
47. Wazwaz, A.M. Compactons in a Class of Nonlinear Dispersive Equations. *Math. Comput. Model.* **2003**, *37*, 333–341.
48. Wazwaz, A.M. The sine-cosine method for obtaining solutions with compact and noncompact structures. *Appl. Math. Comput.* **2004**, *159*, 559–576.
49. Baskonus, H.M. New acoustic wave behaviors to the Davey-Stewartson equation with power-law nonlinearity arising in fluid dynamics. *Nonlinear Dyn.* **2016**, *86*, 177–183.